

DEVICE FOR DETERMINING THE FILLING LEVEL OF A FILLING MATERIAL IN A CONTAINER

Field of the Invention

The present invention relates to a device for determining the filling level of a filling material in a container.

Background of the Invention

In addition to horn, rod and parabolic antennas, use is also made of planar antennas in the technology of measuring filling levels. Refinements of planar antennas are described, for example, in the book "Einführung in die Theorie und Technik planarer Mikrowellenantennen in Mikrostreifenleitungs-technik" ["Introduction to the Theory and Technology of Planar Microwave Antennas in Microstrip Line Technology"], by Gregor Gronau, Verlagsbuchhandlung Nellissen-Wolff or in the journal article "Impedance of a radiating slot in the ground plane of a microstrip line", IEEE Trans. Antennas Propagat., Vol. AP-30, 922-926, May 1982.

A planar antenna usually comprises a dielectric substrate on one side of which the antenna structure is provided, and on the other side of which a conductive coating is provided. An asymmetric stripline is the basis of the most widespread planar antenna structure.

Moreover, it is usually possible to provide cutouts in the conductive layer, in which case supply lines to the cutouts are then to be provided on the other side of the dielectric substrate. These cutouts are, for example, configured and arranged in such a way that the antenna

preferably radiates only electromagnetic waves of a desired mode. A planar antenna for use in an explosive environment is disclosed in Published European Patent Application No. EP 1 083 413 A1. This known solution can, of course, also be used in combination with the invention described in the present application. This known solution is therefore expressly to be ascribed to the disclosure content of the present application.

Usually (Gaussian) delta-shaped pulses, also frequency-modulated continuous signals are used as measuring signals. Both types of measuring signals are relatively broadband. For example, the pulsed measuring signals have a bandwidth of a few hundred megahertz. The planar antennas which have become known are capable, however, only of radiating the measuring signals in a quasi-punctiform frequency range at the resonant frequency in a virtually undamped fashion. As can be seen from Figure 2, all frequency components of the measuring signal which are outside the "resonant frequency" of the cutouts are more or less reflected.

Summary of the Invention

It is the object of the present invention to optimize an antenna in such a way that measuring signals are radiated to the greatest possible extent in a broadband fashion.

This object is achieved by a device which has the following features: a signal-generator unit which generates measuring signals, an input coupling unit and an antenna, the input coupling unit coupling the measuring signals onto the antenna, and the antenna emitting the measuring signals in the direction of the surface of the filling material, and a receiving/evaluating circuit which receives the measuring signals reflected at the surface of the filling material and determines the filling level in the container via the propagation time of the measuring signals. The

antenna has at least one first dielectric layer, the side of the dielectric layer averted from the filling material bearing a feed structure, and the side of the dielectric layer facing the filling material having a plurality of cutouts which at least partially have different dimensions and/or shapes.

The present invention proceeds from the physical fact that the resonant frequency of the cutouts, that is to say the frequency at which a measuring signal is essentially radiated without being damped, is a function of the respective dimensions of the cutouts. In the case of a rectangular slot, this means that the resonant frequency is a function of the length and width of the slot.

According to the present invention, the cutouts now have variable dimensions and are, in particular, configured in such a way that the associated resonant frequencies completely cover a desired frequency range. As a result of this, the complete frequency spectrum of a broadband signal can be radiated virtually unhindered in the direction of the filling material.

In accordance with a preferred refinement of the device according to the present invention, it is provided that the cutouts are slot-shaped recesses, wherein the longitudinal axes of the slots are aligned substantially radially.

The radiation characteristic of the antenna can be further improved by the advantageous developments of the device according to the present invention which are named below: thus, it is provided that one group of cutouts or of slots is arranged in an essentially equidistant fashion at a first distance r_1 from the center of symmetry of the dielectric layer; a second group of cutouts or slots is arranged in an essentially equidistant fashion at a second distance r_2 from the center of symmetry of the dielectric layer. The cutouts or the slots of the at least one further group are preferably arranged at a spacing from the cutouts or slots of the first

group.

Moreover, it has proved to be advantageous when the cutouts are rectangular slots or recessed, and when the dimensions of the slots vary in the range from $0.8 \times a$ to $1.2 \times a$ or $0.8 \times b$ to $1.2 \times b$; in this case, a characterizes the length and b the width of a slot.

In order to prevent deposits from forming on the side of the dielectric layer facing the filling material, in accordance with an advantageous development of the device according to the present invention a dielectric protective layer is provided which is connected to the dielectric layer on the side on which the cutouts or the slots are arranged.

Both the (feed structure) antenna structure and the cutouts are preferably applied to the dielectric layer using an etching process. For example, both sides of the dielectric layer bear a copper coating. One side of the dielectric layer is now treated such that the desired feed structure remains on it; cutouts with the desired dimensions are etched out on the second side. The correct position of the feed structure relative to the cutouts is ensured via register marks.

The planar antenna preferably has a circular cross section. It can then be mounted with relative ease in the stub of a container, which usually likewise has a circular cross section. Consequently, the first dielectric layer and/or the at least one further dielectric layer is/are preferably a circular disk or circular disks.

As already mentioned at a preceding juncture, the antenna is preferably suitable for radiating relatively broadband measuring signals.

The antenna structure and the cutouts or the slots preferably cooperate such that the antenna essentially emits measuring signals of a selected mode. In the radiation of monomode measuring signals, virtually no dispersion at all occurs in the case of guided radiation of the

measuring signals. The echo signals, which reflect the fraction of the measuring signals which is reflected at the surface of the filling material, are then characterized by a defined peak, which is to be assigned with high accuracy to the corresponding filing level.

Brief Description of the Drawings

The invention is explained in more detail with the aid of the following drawings, in which:

Figure 1 shows a schematic of the device according to the present invention.

Figure 2 shows graphs of the return loss of a planar antenna as a function of the frequency in the case of cutouts of equal dimensions (prior art),

Figure 3 shows a plan view of the feed structure in accordance with a preferred embodiment of the device according to the present invention.

Figure 4 shows a plan view of the cutouts in accordance with a preferred embodiment of the device according to the present invention.

Figure 5 shows an illustration of the dielectric layer which bears the structures shown in Figure 3 and Figure 4, and

Figure 6 shows a graph which illustrates the return loss of a measuring signal as a function of the frequency in the case of the planar antenna according to the present invention.

Detailed Description

Figure 1 shows a schematic of the device according to the present invention. An antenna 1 for determining the filling level F of a filling material 3, which is located in a container

2, is mounted in an opening 5 in a lid 4 of the container 2. The antenna 1 is arranged in the opening 5 such that the measuring signals, which are generated in a signal-generating unit 6, strike a surface 9 of the filling material 3 essentially perpendicularly. The measuring signals reflected at the surface 9 are received by the antenna 1 and relayed from there to a receiving/evaluating circuit 7. The receiving/evaluating circuit 7 uses the propagation time for the measuring signals to determine the filling level F of the filling material 3 in the container 2. The principle of the design of a corresponding microwave measuring instrument is known from the prior art. Corresponding instruments are marketed and sold by the applicant's assignee under the designation of Micropilot.

Figure 2 relates to the return loss of a known planar antenna. Reference is made, in turn, in this context to the already cited EP 1 083 413 A1. As may easily be seen from the resonance curve, the amplitude A reaches a minimum at the resonant frequency f_r - the reflection of the measuring signal is therefore minimal here. More or less strong reflections occur in the case of all the remaining frequencies, and this means that the corresponding frequency components experience a reflection. Of course, this has an extremely disadvantageous effect in the case of broadband measuring signals, since only a fraction of the frequency spectrum can still be radiated at all, and thus can reach the surface 9 of the filling material 3.

Figure 3 shows the antenna structure 11 which is used in accordance with a preferred embodiment of the device according to the present invention. The antenna structure 11 is of highly symmetric design. A contact 16 for connecting to an input coupling unit 18 is provided in the region of the center of symmetry 13. Greater detail on this can be found in EP 1 083 413 A1, which has already been cited.

The arrangement and the various dimensions of cutouts 12 are illustrated in Figure

4. The cutouts 12, which were preferably etched out of a conductive layer 15, do not have uniform dimensions but differ from one another with regard to their width b and length a. In the case shown, the cutouts 12 are arranged in two groups, a first group has a distance r_1 from the center of symmetry 13, while the second group of cutouts has a distance r_2 from the center of symmetry 13.

Figure 5 shows an illustration of a dielectric layer 10 in accordance with a preferred refinement of the device according to the present invention. A feed structure 11' is applied to the side of the dielectric layer 10 which is averted from, or does not face the filling material 3; the cutouts 12 are provided on the side of the dielectric layer 10 which faces the filling material 3. The correct position of the feed structure 11' relative to the cutouts 12 is ensured by the register marks 17, which are provided on both sides of the dielectric layer 10.

Shown schematically in Figure 6 is the graph which represents the absolute value of the return loss of the planar antenna as a function of the frequency f in accordance with the solution according to the present invention. Because of the dependence of the resonant frequency f_r on the dimensions of the cutouts 12, in other words, here, on the length a and the width b of the slots, a multiplicity n of resonant frequencies f_m occur which lie relatively close together. In summary, it is therefore possible to generate a frequency band in which the measuring signals are radiated virtually without loss via the antenna 1 according to the present invention.